Journal of Technology and Science Education

STEM ATTRITION AMONG HIGH-PERFORMING COLLEGE STUDENTS IN THE UNITED STATES: SCOPE AND POTENTIAL CAUSES

Xianglei Chen

RTI International

United States

xchen@rti.org

Received September 2014

Accepted January 2015

Abstract

Postsecondary education plays a critical role in building a strong workforce in Science, Technology, Engineering, and Mathematics (STEM) fields. The U.S. postsecondary education system, however, frequently loses many potential STEM graduates through attrition. An increasing portion of STEM leavers are top performers who might have made valuable additions to the STEM workforce had they stayed in STEM fields. Using data from the 2004/09 Beginning Postsecondary Students Longitudinal Study (BPS:04/09), this study tracks a cohort of U.S. beginning bachelor's degree students over 6 years, providing a close look at STEM attrition among a group of high-performing college students. Capitalizing on the transcript data collected through BPS:04/09, this study also examines STEM coursetaking, detailing how participation and performance in undergraduate STEM coursework are associated with students' departure from STEM fields. The study finds that about a quarter of high-performing beginning bachelor's degree students entered STEM fields (i.e., declared a STEM major) during their enrollment between 2003 and 2009, and about a third of these entrants had left STEM fields by spring 2009. The results of multinomial probit regression analysis indicate that students' intensity of STEM coursework in the first year and their performance in STEM courses may have played an important role in their decisions to switch majors out of STEM fields.

Keywords – STEM, STEM attrition, STEM retention, STEM coursetaking, STEM performance, College students.

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1 INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) fields are widely regarded as vital to a nation's economy. Although the United States has long been held as a world leader in scientific and technological innovation, it is facing fierce competition from abroad in producing STEM talent. Various sources indicate that the math and science performance of U.S. secondary school students lags behind their international peers in many nations (Kelly, Xie, Nord, Jenkins, Chan & Kastberg, 2013); the rates at which U.S. undergraduates choose STEM majors trail those of several key competitors (National Science Board, 2010); the United States has one of the lowest ratios of STEM to non-STEM bachelor's degrees among developed nations (National Science Board, 2014); and top U.S. students, who have great potential to become future scientists, engineers, and innovators, are forgoing degrees and careers in STEM fields (Bettinger, 2010; Lowell, Salzman, Bernstein & Henderson, 2009; Zumeta & Raveling, 2002).

Rising concerns about the ability of the United States to compete in the global economy have led to national efforts to increase the number and diversity of students pursuing STEM degrees and careers (National Academy of Science, 2005; National Governors Association, 2007; National Research Council, 2012). A recent policy

report by the President's Council of Advisors on Science and Technology urged U.S. colleges and universities to produce more STEM graduates, announcing that to remain globally competitive, the United States will need 1 million STEM professionals in addition to those currently projected to enter the labor market over the next decade (PCAST, 2012). To produce more STEM graduates, some U.S. policies and researchers have called on reducing college students' attrition from STEM fields, arguing that increasing STEM retention by even a small percentage can be a cost-efficient way to contribute substantially to the STEM workforce (Ehrenberg, 2010; Haag & Collofello, 2008; PCAST, 2012).

1.1 Purpose of this study

In light of our nation's need to build a strong STEM workforce for the future, an examination of STEM attrition in U.S. postsecondary education, particularly among top students, is warranted. Using data from the 2004/09 Beginning Postsecondary Students Longitudinal Study (BPS:04/09), this study tracks a cohort of 2003–04 beginning postsecondary students over 6 years, presenting the most recent national statistics on STEM attrition among a group of students who consistently demonstrated high-level academic performance in college. Capitalizing on the postsecondary transcript data collected through BPS:04/09, this study also provides an analysis of STEM coursetaking, exploring how participation and performance in undergraduate STEM coursework are associated with STEM attrition among top students in U.S. postsecondary institutions. Because a majority of STEM careers require at least a bachelor's degree (Carnevale, Smith & Melton, 2011), this study focuses on students who start their postsecondary education in a bachelor's degree program. Throughout this study, the term STEM attrition refers to enrollment choices that result in potential STEM graduates (i.e., those who declare a STEM major) leaving STEM fields. The purpose of this study is to deepen understanding of STEM attrition in U.S. postsecondary education by addressing the following questions:

- To what extent do high-performing college students enter and subsequently leave STEM fields?
- Who leaves STEM fields? Into which fields do they move?
- Do STEM persisters and leavers differ in STEM coursetaking and performance?
- What predicts STEM attrition among high-performing college students? Which factors are among the most important ones?

In the context of this study, high-performing college students are operationalized in terms of their academic performance during their undergraduate careers (note that data on high school academic performance are limited in BPS:04/09; high school grades, though available in BPS:04/09, were not collected for students age 24 or above). High-performing students are defined as those who demonstrate consistent, high-level performance during their 6-year college enrollment. This variable was derived from students' yearly grade point average (GPA) between 2003 and 2009 as recorded on their transcripts. For example, students with 6 years of GPA records are considered high performers if their GPAs were 3.5 or higher for at least 5 out of 6 years and none of their yearly GPAs were below 2.5. For the purpose of comparison, this study also includes two additional groups —low- and moderate-performing students. Students with 6 years of GPA records are considered low performers if their GPAs were below 2.5 for at least 5 out of 6 years and none of their yearly GPAs were 3.5 or above. The remaining students with 6 years of GPA records are considered moderate performers. The same logic applies to students with 5 or fewer years of GPA records.

To provide a context for the analyses and facilitate discussions, the following sections present a brief review of research literature, define several key terms used in this study, and describe the data sources, sample, and methodology used for the analyses.

1.2 Literature review

Although one-third of students express interest in STEM majors before starting college (National Science Board, 2012), the actual STEM enrollment rate is not that high. For example, STEM majors accounted for just 14 percent of all undergraduates enrolled in U.S. postsecondary education in 2007–08 (Snyder & Dillow, 2013). For various reasons, a significant portion of students who initially intend to study STEM fields abandon them several years later. A report published by the U.S. Department of Education found that 56 percent of beginning postsecondary students who declared STEM majors in their freshman year left these fields over the next 6 years (Chen, 2009). Several studies also found that many STEM leavers were top students who might have made valuable additions to the STEM workforce had they persisted and earned degrees in STEM fields (Bettinger,

2010; Lowell, Salzman, Bernstein & Henderson, 2009; Seymour & Hewitt, 1997). The extent and causes of STEM departure among top students, however, have not been extensively examined.

Studies frequently find that women, non-Asian minorities, first-generation students (i.e. those who are the first members of their families to attend college), and those from low-income backgrounds leave STEM fields at higher rates than do their counterparts (Anderson & Kim, 2006; Griffith, 2010; Hill, Corbett & Rose, 2010; Kokkelenberg & Sinha, 2010; Shaw & Barbuti, 2010). In addition, STEM attrition occurs more frequently among students with weaker academic backgrounds (LeBeau, Harwell, Monson, Dupuis, Medhanie & Post, 2012; Méndez, Buskirk, Lohr & Haag, 2008; Whalen & Shelley, 2010). There is also evidence linking STEM attrition to such attitudinal factors as motivation, confidence, and beliefs about one's capacity to learn STEM subjects: students who are less motivated to study STEM, lack confidence in their abilities to complete STEM programs, and have low self-efficacy towards STEM learning tend to leave STEM fields at higher rates than do their counterparts (Burtner, 2005; Wang, Eccles & Kenny, 2013).

Anecdotal evidence and small-scale studies have identified several course-related factors that may explain why students lose their interest in STEM programs, including negative experiences encountered in gatekeeper or introductory math and science courses; limited exposure to STEM coursework in the first 2 years in college; and poor performance in STEM courses, especially relative to performance in non-STEM courses (Bettinger, 2010; Barr, Gonzalez & Wanat, 2008; Mervis, 2010; Ost, 2010; Rask, 2010; Seymour, 2001; Seymour & Hewitt, 1997; Stinebrickner & Stinebrickner, 2011). These findings, however, have not been validated using nationally representative data.

Students' experiences or perceptions of institution and workplace context/climate may also contribute to STEM attrition. Such factors include inadequate academic advising, career counseling, and institution support; feelings of isolation in STEM fields because too few peers pursue STEM degrees and too few role models and mentors are available (mainly pertinent to women and underrepresented minorities); distaste for the competitive climate in STEM departments (women especially); perceived discrimination on the basis of sex and/or race/ethnicity in the STEM workforce; and attraction of lucrative careers such as health care and business (Bettinger, 2010; Carrell, Page & West, 2010; Chang, Eagan, Lin & Hurtado, 2011; Daempfle, 2003; Eagan, Herrera, Garibay, Hurtado & Chang, 2011; Espinosa, 2011; Fouad et al., 2010; Gayles & Ampaw, 2014; Price, 2010; Shaw & Barbuti, 2010). These contextual and climate factors are now considered as areas worthy of investigation for explaining the departure of students (especially women and minorities) from STEM fields, although these data are rarely collected by national surveys.

The review of past research suggests that students' decisions to leave STEM fields are likely to arise from a multitude of factors, underscoring the need to examine models of STEM attrition that include multiple factors simultaneously. In light of this review, the analyses in this study encompass as many related factors as available in BPS:04/09. Past research has already provided extensive insights into demographic and prior college characteristics; therefore, this study pays special attention to STEM coursetaking and performance and their role in STEM attrition.

To facilitate discussions of the analyses and results, Table 1 provides the definitions of key terms used in this study.

1. STEM fields	*This study defines the following fields as STEM: mathematics; physical sciences; biological/life sciences; computer and information sciences; engineering/engineering technologies; and science technologies.*
2. Non-STEM fields	*Non-STEM fields include all fields that are not STEM fields. This study particularly focuses on the following five non-STEM fields with adequate sample sizes in BPS:04/09: social/behavioral sciences; humanities; business; education; and health sciences.*
3. STEM entrance	*STEM entrance refers to a student's majoring in a STEM field. In BPS:04/09, STEM entrance can be identified at three points in time: during the 2004 base-year survey and during the 2006 and 2009 follow-up surveys. Any student who reported a STEM major at one or more of these three survey times is considered a STEM entrant in this study.*
4. STEM leavers	*STEM leavers are a subgroup of STEM entrants who leave STEM fields either by switching their major to a non-STEM field or by leaving postsecondary education without earning a degree or certificate. In BPS:04/09, STEM leavers consist of STEM entrants who had not attained any degree or certificate by 2009 and were not enrolled in that year; were enrolled in a non-STEM field in 2009; and were not enrolled in 2009 and had attained one or more degrees as of 2009 but whose last degree was in a non-STEM field.*
5. STEM persisters	*STEM persisters are a subgroup of STEM entrants who persist in STEM fields. In BPS:04/09, STEM persisters consist of STEM entrants who either were enrolled in a STEM field in 2009 or, if not enrolled that year, had attained their last degree in a STEM field.*
6. STEM attrition rate	*The rate is the number of STEM leavers divided by the total number of STEM entrants.*

Table 1. Definition of key terms related to STEM

1.3 Data sources, study sample, and methodology

The analysis described in this study is based on data from the 2004/09 Beginning Postsecondary Students Longitudinal Study (BPS:04/09) and the associated 2009 Postsecondary Education Transcript Study (PETS:09). BPS:04/09 followed a cohort of students who began postsecondary education in 2003−04 for a total of 6 years, through 2009. BPS sample members were initially identified in the 2003–04 National Postsecondary Student Aid Study (NPSAS:04, a nationally representative study that examines how undergraduate, graduate, and first-professional students and their families pay for postsecondary education. Approximately 19,000 NPSAS:04 sample members were confirmed as first-time beginning students; among them, about 16,700 became the base sample of BPS:04/09. Interviews were then conducted three times: in 2004, at the end of their first year in postsecondary education; in 2006, about 3 years after their initial college entry; and in 2009, about 6 years after they first enrolled. Through student interviews and other sources, data on students' demographic characteristics; their persistence in and completion of postsecondary education programs; transition into employment; marital status, income, and debt, among other indicators, were collected. In 2009, BPS:04/09 also collected transcript data from every institution that BPS students attended between July 2003 and June 2009. About 91 percent of BPS04/09 sample members had at least one transcript available for analysis. The transcripts provide a detailed portrait of students' coursetaking, credit accumulation, academic performance, and degree histories.

To provide a longitudinal look at STEM attrition over 6 years in college, this study focuses on a subsample of BPS:04/09 students who participated in the initial survey in 2003−04 as well as in the two follow-up surveys in 2006 and 2009. Because many variables in this study are transcript based, the sample is narrowed to students who had transcript data available for analyses. Since most STEM occupations require a bachelor's degree, the sample is further restricted to students who began their postsecondary education in a bachelor's degree program. After these selections, the final study sample consists of about 7,400 beginning bachelor's degree students.

Table 2 presents the characteristics of the study sample used in this study. Nearly 20 percent of sample members are high performers, 16 percent low performers, and the remaining 64 percent moderate performers. The study sample has more females (55 percent) than males (45 percent). About 32 percent of sample members are minorities, 21 percent are first-generation students, and 20 percent come from low-income background. Most sample members (63 percent) began their postsecondary education at a public 4-year

institution, and 37 percent began at a private 4-year institution. While 26 percent of sample members started at a highly selective 4-year institution, 20 percent started at a nonselective or open-admission institution.

All beginning bachelor's degree students	100.0
Academic performance level in college	
Low level	16.3
Moderate level	64.0
High level	19.6
Sex	
Male	44.7
Female	55.3
Race/ethnicity	
White	68.4
Black/Hispanic	20.6
Asian	5.9
Other	5.0
Highest education of parents	
High school or less	20.7
Some college	21.8
Bachelor's degree or higher	57.5
Income level in 2003–04	
Lowest quartile	19.5
Lower middle quartile	23.1
Upper middle quartile	25.3
Highest quartile	32.0
Type of first-attended institution	
Public 4-year	63.2
Private nonprofit 4-year	33.1
Private for-profit 4-year	3.8
Selectivity of first-attended institution	
Minimally selective/open admission	19.8
Moderately selective	54.1
Highly selective	26.1

NOTE: Details may not sum to 100 percent due to rounding

Table 2. Characteristics of the study sample

The study begins with descriptive analyses that present national statistics on STEM entrance and attrition rates among high-performing students; compare students' attrition rates in STEM and non-STEM fields; examine the characteristics of those who left STEM fields and the fields into which they moved; and identify differences between STEM leavers and persisters in their STEM coursetaking and performance in college.

Built on the bivariate results, the study then uses multivariate regression to explore the association of various factors with STEM attrition, while taking into account the interrelationship of these factors. The purpose of this multivariate analysis is twofold: to determine whether after controlling for various factors, high-performing students differ from other students in terms of their way of exiting STEM fields; and to identify the factors associated with high-performing students' departure from STEM fields.

Because students who enter STEM fields can have multiple STEM outcomes (e.g., they can persist in a STEM field; they can switch majors and pursue a non-STEM field; or they can quit school entirely without earning a degree or certificate), multinomial probit (MNP) regression is chosen for the multivariate analysis in this study. MNP is one of the most common statistical techniques used to predict the probability of a respondent choosing a certain outcome out of several mutually exclusive alternatives (Borooah, 2001).

Assuming that each individual faces a set of outcomes, an MNP model formulation may be written as follows:

$$y^*_{ij} = x'_i\beta_j + \varepsilon_{ij}$$

where i (= 1, 2, …, N) represents an individual; j (= 1, 2, …, M) represents one of M different outcomes of the dependent variable yi; x'_i is a vector of independent variables that may be associated with or influence an individual's outcome or choice; and the error term, ε_i's, is assumed to follow a multivariate normal distribution. MNP assumes that each individual chooses the option yielding the highest utility of all alternatives. That is, an individual i chooses the outcome j if the outcome y^*_{ij} is the highest for j:

$$y_i = \begin{cases} j \text{ if } y^*_{ij} = \max\,(y^*_{i1}, y^*_{i2}, \ldots, y^*_{iM}) \\ 0 \text{ otherwise} \end{cases}.$$

The probability of an individual i choosing outcome j is conditional on or a function of the set of independent variables, x'_is:

$$p\,(y_i = j \mid x_i) = F_j\,(x'_i, \varepsilon_i)\ (\text{j} = 1,\ldots, \text{M, i} = 1,\ldots, \text{N})$$

where for a probit analysis, F represents a cumulative probability function based on the normal distribution. Only M−1 of the probabilities can be freely specified because the probability for all alternatives sum to one (i.e., $p(y_i = 1) + p(y_i = 2) + \ldots + p(y_i = M) = 1$). More details on MNP model specifications used in the study are provided in the discussion of multivariate results below.

2 STEM ENTRANCE, DEPARTURE, COURSETAKING, AND PERFORMANCE

Figure 1 shows STEM entrance rates based on students' reported major fields. About 28 percent of 2003–04 beginning bachelor's degree students entered a STEM field at some point during their enrollment between 2003 and 2009. The STEM entrance rate for high-performing students was 26 percent, which was not significantly different from the STEM entrance rates for low- and moderate-performing students (24 percent and 29 percent, respectively).

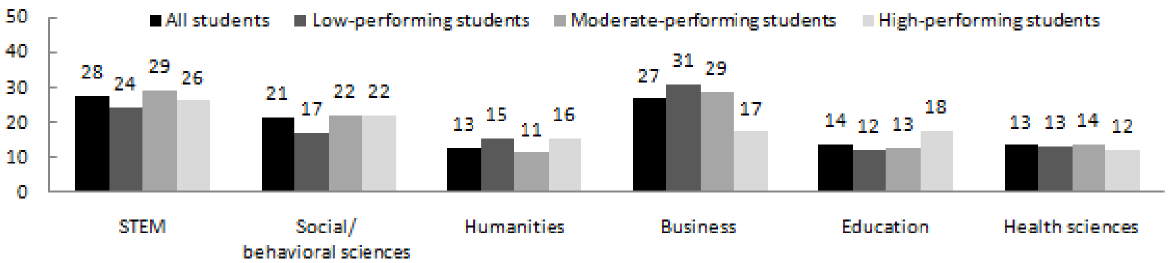


Figure 1. Percentage of students who entered STEM and selected non-STEM fields: 2003-2009

Figure 1 also shows that among various fields, STEM was one of the most popular fields for undergraduates: 28 percent of beginning bachelor's degree students chose a STEM major at some point, while 13–14 percent chose a humanity, education, or heath science major. STEM also attracted proportionally more high-performing students than did many non-STEM fields: 26 percent of high-performing students entered STEM fields, while 12–22 percent of high-performing students entered social/behavioral science, humanity, business, education, or health science fields.

Many STEM entrants leave STEM fields several years later (Chen, 2009). Figure 2 shows that among 2003–04 beginning bachelor's degree students who entered STEM fields between 2003 and 2009, nearly one-half (48

percent) had left these fields by spring 2009. Some left STEM fields by switching majors (28 percent), while others left by exiting college entirely without earning a credential (20 percent).

The STEM attrition rate among high-performing students was relatively lower, however: 36 percent of high-performing students who entered STEM fields between 2003 and 2009 had left these fields by spring 2009. In comparison, the STEM attrition rate among low-performing students was much higher, at 71 percent. In addition, low- and high-performing students appeared to exit STEM fields in different ways. While low-performing students were more likely than high-performing students to leave STEM fields via dropping out of college (57 percent vs. 10 percent), high-performing students were more likely than low-performing students to leave STEM fields via switching majors (26 percent vs. 14 percent).

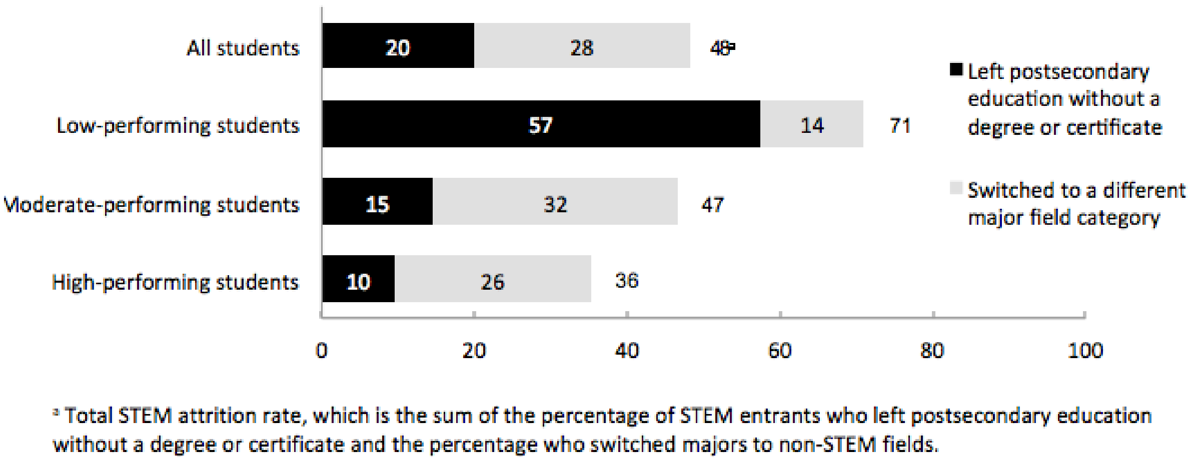


Figure 2. Percentage of STEM entrants who left STEM fields: 2003-2009

Many non-STEM fields experienced similar or higher attrition rates. As shown in Figure 3, students in humanities, education, and health sciences had higher attrition rates than did those in STEM fields (56–63 percent vs. 48 percent), and students in business and social/behavioral sciences had attrition rates of similar magnitude (50 percent and 45 percent, respectively) as did students in STEM fields.

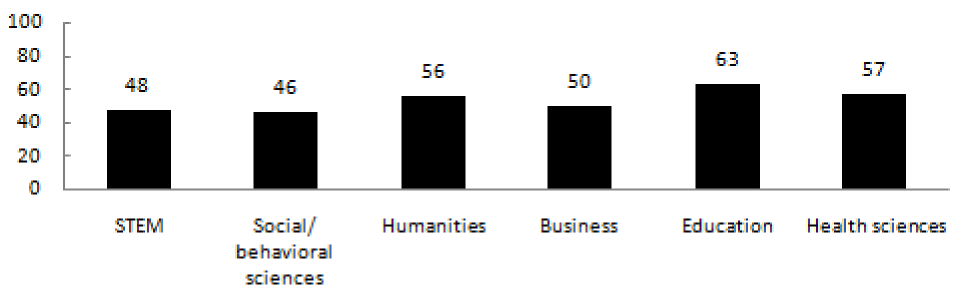
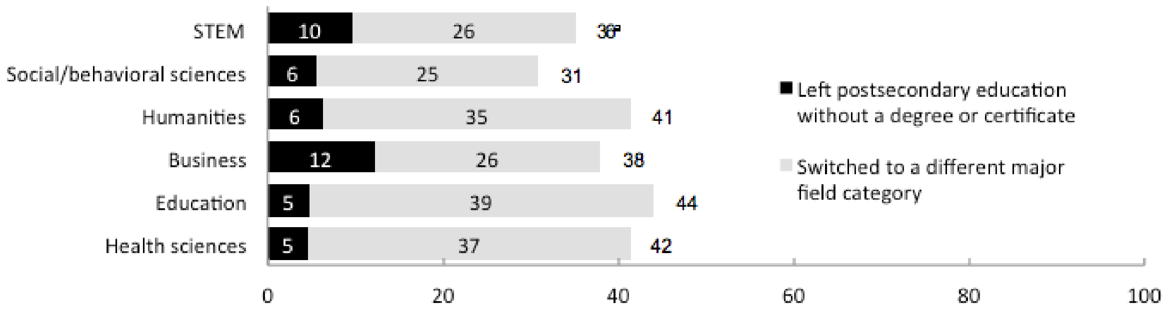


Figure 3. Attrition rates in STEM and selected non-STEM fields

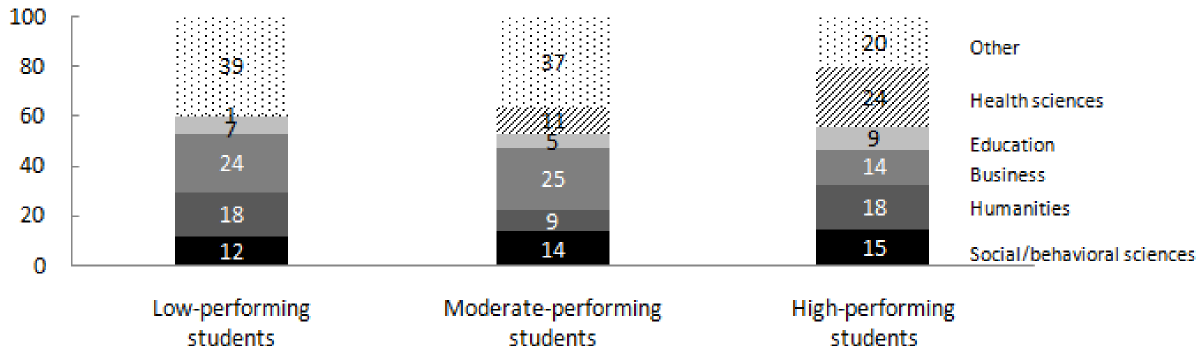
Figure 4 focuses on high-performing students and shows that their STEM attrition rate (36 percent) was comparable to or lower than their attrition rates in non-STEM fields (31–44 percent). In addition, high-performing students entering education, health sciences, and humanities were more likely than high-performing students entering STEM fields to switch majors later (35–39 percent vs. 26 percent).



[a] Total STEM attrition rate, which is the sum of the percentage of STEM entrants who left postsecondary education without earning a degree or certificate and the percentage who switched majors to non-STEM fields. Attrition rates in selected non-STEM fields were calculated in the same way.

Figure 4. Attrition rates in STEM and selected non-STEM fields among high-performing students

Figure 5 shows the last major field reported by STEM entrants who changed majors and reveals that low- and high-performing students tended to move to different fields. For example, business was the most frequent destination for low-performing students: about a quarter of low-performing students who entered STEM fields but changed majors later ended up in business. For high-performing students, the field of health sciences was a popular destination: a total of 24 percent of high-performing students who entered STEM fields but changed majors later ended up in a health science field. Overall, education was the least chosen field for switching majors among all performance groups: the percentage of STEM entrants who switched to an education major was 7 percent for low-performing students, 5 percent for moderate-performing students, and 9 percent for high-performing students.



NOTE: Details may not sum to 100 percent due to rounding.

Figure 5. Last major field reported by STEM entrants who switched majors

Table 3 shows the characteristic of STEM entrants who left STEM fields. Although the table presents data for all performance groups, the discussion below focuses on high-performing students. Overall, few high-performing students left STEM fields by dropping out of college (10 percent, see Figure 2); but among those who did leave STEM this way, they were more likely to be male students (13 percent); first-generation students (22 percent); students who did not take math courses beyond Algebra II/trigonometry in high school (11 percent); students who first attended the least selective 4-year institutions (26 percent); and students who first attended private for-profit 4- year institutions (74 percent).

Selected characteristics	Low-performing students		Moderate-performing students		High-performing students	
	Left PSE without a degree or certificate[a]	Switched to a non-STEM major	Left PSE without a degree or certificate[a]	Switched to a non-STEM major	Left PSE without a degree or certificate[a]	Switched to a non-STEM major
All STEM entrants	57.5	13.5	14.6	32.1	9.6	25.6
Sex						
Male	58.1	13.6	16.8	29.5	12.8	20.8
Female	55.3	13.3	10.8	36.5	6.1	30.8
Race/ethnicity						
White	58.0	13.8	14.8	32.0	10.9	26.2
Black/Hispanic	61.8	13.4	17.0	37.5	11.7	25.7
Asian	50.8	6.8	6.2	22.8	0.6	17.2
Other	41.4	18.6	15.9	25.2	11.1	47.4
Highest education of parents						
High school or less	69.9	5.7	15.6	37.6	21.9	23.8
Some college	66.2	19.3	16.0	30.1	4.3	21.4
Bachelor’s degree or higher	46.5	15.4	14.0	30.6	8.4	26.5
Income level in 2003–04						
Lowest quartile	64.4	13.4	19.7	35.5	5.2	23.1
Lower middle quartile	63.0	8.1	17.8	34.0	2.0	22.5
Upper middle quartile	54.7	15.6	12.3	30.2	9.8	22.0
Highest quartile	46.2	16.2	11.0	30.0	15.0	30.8
High school grade point average (GPA)						
Less than 3.00	58.6	10.7	21.9	37.6	0.0	37.3
3.00–3.49	51.0	17.3	16.0	36.6	6.1	33.3
3.50 or higher	62.3	11.2	10.8	28.0	6.5	24.0
Highest math in high school						
Algebra II/trigonometry or below	51.6	14.7	21.1	36.4	11.4	36.1
Pre-calculus	63.4	12.1	13.7	36.5	3.4	27.2
Calculus	57.9	14.5	9.4	25.0	5.1	22.5
Selectivity of first-attended institution						
Minimally selective/open admission	71.1	3.9	30.5	37.9	26.2	18.7
Moderately selective	50.1	16.6	13.8	33.4	6.7	26.9
Highly selective	54.9	20.8	7.9	26.7	6.2	26.8
Type of first-attended institution						
Public 4-year	57.8	14.4	12.9	34.4	7.4	28.3
Private nonprofit 4-year	61.1	13.3	16.0	26.6	5.1	24.8
Private for-profit 4-year	36.3	0.0	44.8	37.2	74.4	0.0

Table 3. Characteristics of STEM entrants who left STEM fields

High-performing students who left STEM fields via switching majors had somewhat different characteristics: they tended to be female (31 percent) or students who were from high-income backgrounds (31 percent), earned a high school GPA of below 3.0 (37 percent), did not take math courses beyond algebra II/trigonometry in high school (36 percent), or first attended moderately or highly selective 4-year institutions (27 percent). These patterns suggest that STEM leavers via dropping out of college may be different from STEM leavers via switching majors in terms of their intention, motivation, and reasons for their exit from STEM fields.

The substantial outflow from STEM fields by the end of the first year has been well documented, underscoring the importance of examining first-year data (Chang, Cerna, Han & Sáenz, 2008; Seymour & Hewitt, 1997). The transcript data from BPS:04/09, summarized in Table 4, show that STEM persisters had a stronger focus on

STEM coursework in the first year than did STEM leavers. For example, among high-performing students who entered STEM fields between 2003 and 2009, nearly 100 percent of those who persisted in STEM fields through 2009 (vs. 89 percent of STEM leavers) earned some STEM credits in the first year; and on average, STEM persisters earned a total of 19 STEM credits (vs. 13 credits earned by STEM leavers) in the first year. These differences were observed among other performance groups as well.

STEM persisters and leavers were also distinguished by their first-year math coursetaking: proportionally more STEM persisters than STEM leavers took advanced math courses such as calculus in the first year. For example, among high-performing students who entered STEM fields between 2003 and 2009, 71 percent of those who persisted in STEM fields took calculus or advanced math in the first year, compared with 31–47 percent of those who subsequently left college or switched majors.

The reason to leave STEM fields may also have to do with student performance in STEM courses. Table 4 shows that STEM leavers tended to earn a lower STEM grade relative to their non-STEM grade and have higher levels of withdrawn/failed STEM courses than did STEM persisters. For example, among moderate-performing students who entered STEM fields, 24 percent of those who dropped out of college, 16 percent of those who switched majors, but just 4 percent of STEM persisters earned an overall STEM grade that was lower than their non-STEM grade by at least 1 grade point. Among low-performing students, the percentage of withdrawn/failed STEM courses in all STEM courses attempted through 2009 was 16 percent for STEM leavers who dropped out of college and 11 percent for STEM leavers who switched majors, but just 7 percent for those who persisted in STEM fields through 2009. These patterns were largely similar among other performance groups, although some differences were not significant due to smaller samples.

Performance level/STEM leavers or persisters	*Percent of students who earned any STEM credits in the first year*	*Average STEM credits earned in the first year*[a]	*Percent of students who took calculus/ advanced math in the first year*	*Percent of students whose STEM GPA was lower than non-STEM GPA by at least 1.0 grade point*	*Percent of withdrawn/ failed STEM courses in all STEM courses attempted thru 2009*[b]
Low-performing students	***86.9***	***9.8***	***25.5***	***17.8***	***12.8***
STEM leavers, total	*84.8*	*8.6*	*23.4*	*16.9*	*15.4*
Left PSE without a degree or certificate[c]	*82.0*	*8.3*	*19.9*	*17.9*	*16.3*
Switched major	*96.6*	*9.6*	*39.5*	*13.0*	*11.4*
STEM persisters	*92.1*	*12.7*	*30.7*	*11.8*	*6.6*
Moderate-performing students	***94.5***	***13.6***	***42.8***	***10.6***	***4.7***
STEM leavers, total	*91.1*	*10.9*	*28.9*	*18.3*	*6.3*
Left PSE without a degree or certificate[c]	*90.1*	*12.0*	*29.5*	*24.2*	*7.4*
Switched major	*91.5*	*10.4*	*28.6*	*15.7*	*5.8*
STEM persisters	*97.4*	*15.9*	*54.6*	*4.1*	*3.2*
High-performing students	***95.9***	***16.8***	***61.0***	***0.7***	***1.4***
STEM leavers, total	*88.6*	*12.6*	*42.3*	*2.0*	*2.3*
Left PSE without a degree or certificate[c]	*78.2*	*13.1*	*30.7*	*6.6*	*3.6*
Switched major	*92.6*	*12.4*	*46.7*	*0.4*	*1.8*
STEM persisters	*99.7*	*18.8*	*70.8*	*0.0*	*1.0*

[a] *Estimates based only on students who earned STEM credits in the first year.*

[b] *Estimates based on students who attempted STEM credits through 2009.*

[c] *"PSE" refers to postsecondary education.*

Table 4. STEM coursetaking and performance by STEM persisters and leavers

3 MULTIVARIATE RESULTS

The bivariate analyses above did not take into account potentially complex relationships among multiple, often related, factors. This section describes the results of a multivariate analysis that introduces multiple factors simultaneously and allows for examination of how each factor is associated with STEM attrition, net of the others. This analysis refines the preceding bivariate analyses by analyzing the relative strength of associations of various factors with STEM attrition, while taking into account the interactions of multiple factors.

3.1 Model specifications

After entering a STEM field, students can have several possible STEM outcomes: they can persist and eventually earn a degree in a STEM field; they can switch majors and pursue a non-STEM degree; or they can quit school entirely before earning a credential. In order to examine the simultaneous association of these multiple discrete outcomes with various related factors, a multinomial probit (MNP) regression model is used. More specifically, the MNP model in this study focuses on the two STEM attrition outcomes (i.e., switching majors and leaving college without a credential), using "persisting in STEM fields" as the base category.

Two MNP regressions are run. The first one determines whether high-performing students have a different probability of leaving STEM fields than other students after controlling for various factors. Built on the results of the first regression, the second regression restricts the sample to high-performing students, identifying the factors that are associated with STEM departure for this group. Thus, the first model includes all STEM entrants, and the second model includes a subsample of STEM entrants who are high-performing students.

3.2 Independent variables

Many factors have been identified in the literature as potentially important to STEM attrition. As indicated by the literature review above, these factors include (but are not limited to) demographic characteristics, precollege academic preparation, institutional context, climate and support, and coursetaking and performance. The MNP models below attempt to include as many of these factors as available in BPS:04/09 to examine their associations with STEM outcomes while controlling for the interrelationships among these factors.

Specifically, for demographic characteristics, the MNP models include sex, race/ethnicity, parental education, and income. For precollege academic preparation, two high school variables are included in the MNP models: overall GPA and the highest level of math course taken. While high school GPA measures students' overall academic preparation for college, the kind of math courses taken indicates the level of math preparation students bring to college.

Although institutional climate, support, and resources for STEM learning and faculty characteristics have been identified as potential factors associated with STEM attrition, none of these variables are available in BPS:04/09. Instead, this study uses the type and selectivity of the initial 4-year institution as proxies for institution contextual factors for STEM learning.

Finally, the amount of STEM coursework in college (especially in the first year), the type of STEM courses taken (particularly in math), and how well students perform in STEM fields, especially relative to the performance in non-STEM fields, are figured prominently in students' decisions to leave STEM fields. These experiences are represented by the following variables: percentage of STEM credits in all credits earned in the first year, the highest math course taken in the first year, percentage of withdrawn/failed STEM courses in all STEM courses attempted through 2009, and STEM GPA relative to non-STEM GPA in the first year as well as through 2009.

3.3 Leaving STEM fields: Switching majors or dropping out of college?

Table 5 presents the MNP results for the two types of STEM attrition—changing majors and leaving college—compared with the base category, "persisting in STEM fields." This analysis mainly determines whether students with different performance levels leave STEM fields in different ways after controlling for related factors. To provide an easier interpretation of the regression results, two estimates are presented in the table: the average marginal effect (AME) and the average predicted probability (APP). The AME represents the average percentage point change in the predicted probability of leaving STEM fields associated with a one-unit change in an independent variable, holding all other independent variables constant in the model. A significant AME for an

independent variable suggests that the observed change in the predicted probability is significantly different from zero, meaning the independent variable has a significant association with the outcome variable after controlling for other independent variables in the model. APP represents the average predicted probability of leaving STEM fields for a particular group of students (e.g., high-performing students) after controlling for all other independent variables in the model.

The bivariate analysis above shows that low-performing students were more likely than high-performing students to leave STEM fields by dropping out of college, while high-performing students were more likely than their low-performing counterparts to leave STEM fields by switching majors. This finding remains even after controlling for many other factors in the multivariate analysis. The average predicted probability of leaving college without earning a degree or certificate was 41 percent for low-performing STEM entrants, which was about 32 percentage points higher than that for their high-performing counterparts (9 percent). On the other hand, the average predicted probability of switching majors for high-performing students was 25 percentage points higher than that for low-performing students (36 percent vs. 11 percent). These results suggest that all other factors being equal, high-performing students were more prone to leave STEM fields by switching majors than low-performing students, who were more prone to leave STEM fields by dropping out of college.

Characteristics	***Left STEM field by switching major to a non-STEM field***		***Left STEM field by leaving PSE without a degree or certificate[a]***	
	Average marginal effect	***Average predicted probability***	***Average marginal effect***	***Average predicted probability***
Academic performance level in college				
Low	-0.25	11.1***	0.32	41.1***
Moderate	-0.07	28.7	0.05	14.4*
High	†	35.9	†	9.1
Sex				
Female	0.02	27.9	-0.06	14.2**
Male	†	26.1	†	20.0
Race/ethnicity				
Black	0.08	34.7	-0.02	17.5
Hispanic	-0.05	21.8	-0.03	15.7
Asian	-0.03	24.0	-0.07	11.7*
All other races	-0.02	24.5	0.01	20.5
White	†	27.0	†	19.2
Highest education of parents				
High school or less	-0.02	25.8	0.00	17.9
Some college	-0.03	24.8	-0.01	17.6
Bachelor's degree or higher	†	27.5	†	18.2
Income level in 2003–04				
Lowest quartile	-0.01	26.7	0.09	25.1*
Lower middle quartile	0.00	27.4	0.03	18.8
Upper middle quartile	-0.02	25.4	-0.02	14.4
Highest quartile	†	27.6	†	16.3
High school grade point average (GPA)				
Unknown	0.06	31.2	0.00	19.1
Less than 3.00	0.00	25.3	-0.03	16.5
3.00–3.49	0.04	29.2	-0.02	17.1
3.50 or higher	†	24.9	†	19.2
Highest math in high school				
Unknown	-0.04	21.2	0.07	24.6
Algebra II/trigonometry or below	0.02	27.4	0.00	17.6
Pre-calculus	0.04	29.1	0.01	18.3
Calculus	†	25.3	†	17.5

Characteristics	*Left STEM field by switching major to a non-STEM field*		*Left STEM field by leaving PSE without a degree or certificate[a]*	
	Average marginal effect	*Average predicted probability*	*Average marginal effect*	*Average predicted probability*
Selectivity of first-attended institution				
Minimally selective/open admission	-0.04	26.2	0.14	29.0***
Moderately selective	-0.04	25.6	0.01	15.5
Highly selective	†	29.9	†	14.5
Type of first-attended institution				
Private nonprofit 4-year	-0.08	22.2**	0.03	19.2
Private for-profit 4-year	-0.26	4.0***	0.16	32.4
Public 4-year	†	30.0	†	16.6
Percent of STEM credits out of all credits earned in the first year				
Lower than 25 percent	0.24	41.1***	0.02	19.4
25–49 percent	0.15	32.2***	0.01	18.7
50 percent or higher	†	17.4	†	17.3
Highest math in the first year				
No math	0.05	29.0	0.02	19.6
Precollege-level math	0.03	27.1	0.05	21.9
Introductory math	0.06	29.8	0.00	17.0
Calculus/advanced math	†	24.0	†	17.2
STEM GPA compared to non-STEM GPA in the first year				
Lower by at least 1.0 grade point	0.07	31.6	0.01	19.3
Lower by 0.5 to 0.9 grade points	0.05	29.7	-0.01	16.9
About the same or higher	†	24.5	†	18.2
Percent of withdrawn/failed STEM courses in all STEM courses attempted through 2009				
More than 20 percent	0.15	40.9*	0.17	32.7**
10–20 percent	0.04	30.0	0.09	24.7**
Less than 10 percent	†	25.8		15.5
STEM GPA compared to non-STEM GPA through 2009				
Lower by at least 1.0 grade point	0.09	33.6	0.09	26.5*
Lower by 0.5 to 0.9 grade points	0.05	29.7	-0.01	16.1
About the same or higher	†	24.8	†	17.5

**p< .05, ** p< .01, *** p< .001.*
† Not applicable for the comparison group.
a "PSE" refers to postsecondary education.
NOTE: F-test for this MNP regression model is 6.30 (p<0.001). The table includes all beginning bachelor's degree students who entered STEM fields between 2003 and 2009 (i.e., STEM entrants). The base category for this MNP is "persisting in STEM fields."

Table 5. Average marginal effects of various characteristics on the probability of STEM entrants leaving STEM fields, and the average predicted probability of leaving STEM fields among various groups of students

3.4 Which factors are associated with switching majors among high-performing students?

Because the vast majority of high-performing students who left STEM fields did so via switching majors, the subsequent MNP regression model focuses only on this outcome (note that a MNP regression model was run for the outcome of "leaving STEM fields by dropping out of college"; however, the model could not be converged due to the small sample size). The results, shown in Table 6, reveal that for high-performing students, the amount of first-year STEM coursetaking and performance in such coursework were among the most important factors associated with the outcome of switching majors.

Specifically, the amount of STEM courses taken in the first year figured prominently in high-performing STEM entrants' likelihood of switching majors. For example, all other factors being controlled in the model, STEM entrants with lower STEM credit loads in the first year (i.e., less than 25 percent of total credits earned in STEM fields) had a higher probability of switching majors than did their counterparts with higher first-year STEM credit loads (i.e., 50 percent or more of total credits earned in STEM fields) (61 percent vs. 18 percent).

The level of withdrawn/failed STEM courses was another key factor in students' likelihood of switching majors: those who withdrew or failed at least 20 percent of their STEM courses (as opposed to less than 10 percent) had a higher probability of switching to non-STEM majors (54 percent vs. 26 percent). Furthermore, STEM entrants whose first-year STEM grades were lower than their non-STEM grades by at least 1 grade point had a higher probability of switching majors than did those whose STEM grades were equal to or higher than their non-STEM grades (68 percent vs. 24 percent). The pattern was similar when looking at grades accumulated over 6 years of enrollment: students whose cumulative STEM grades through 2009 were lower than their non-STEM grades by at least 1 grade point had a higher probability of switching majors than did students whose cumulative STEM grades were equal to or higher than their non-STEM grades (99 percent vs. 26 percent).

Several subgroups also had a higher likelihood of switching majors out of STEM fields after controlling for various factors. Specifically, compared with white STEM entrants, black STEM entrants had a higher probability of switching majors (77 percent vs. 24 percent). In addition, STEM entrants who first attended highly selective institutions had a somewhat higher probability of switching majors than did their counterparts who first attended moderately selective institutions (33 percent vs. 22 percent). Finally, STEM entrants who first attended public 4-year institutions had a higher probability of switching majors than did their counterparts who first attended private for-profit 4-year institutions (29 percent vs. 0.1 percent).

Characteristics	***Left STEM field by switching major to a non-STEM field***	
	Average marginal effect	***Average predicted probability***
Sex		
Female	0.01	26.9
Male	†	*26.1*
Race/ethnicity		
Black	0.53	76.7**
Hispanic	-0.09	14.9
Asian	0.04	28.2
All other races	0.31	55.1
White	†	*24.0*
Highest education of parents		
High school or less	0.08	33.9
Some college	-0.04	22.3
Bachelor's degree or higher	†	*26.2*
Income level in 2003–04		
Lowest quartile	-0.10	23.6
Lower middle quartile	-0.14	19.4
Upper middle quartile	-0.08	25.1
Highest quartile	†	*33.1*
High school grade point average (GPA)		
Unknown	0.02	26.1
Less than 3.00	0.12	36.2
3.00–3.49	0.16	40.6
3.50 or higher	†	*24.1*
Highest math in high school		
Unknown	0.23	48.1
Algebra II/trigonometry or below	0.04	29.0
Pre-calculus	0.00	25.6
Calculus	†	*25.4*

Characteristics	*Left STEM field by switching major to a non-STEM field*	
	Average marginal effect	*Average predicted probability*
Selectivity of first-attended institution		
Minimally selective/open admission	-0.11	22.0
Moderately selective	-0.11	21.7*
Highly selective	†	*32.5*
Type of first-attended institution		
Private nonprofit 4-year	-0.05	23.5
Private for-profit 4-year	-0.29	0.1***
Public 4-year	†	*28.7*
Percent of STEM credits out of all credits earned in the first year		
Lower than 25 percent	0.44	61.3***
25–49 percent	0.15	32.3**
50 percent or higher	†	*17.5*
Highest math in the first year		
No math	-0.03	20.8
Precollege-level math	0.06	30.7
Introductory math	0.14	37.9
Calculus/advanced math	†	*24.3*
STEM GPA compared to non-STEM GPA in the first year		
Lower by at least 1.0 grade point	0.44	68.3**
Lower by 0.5 to 0.9 grade points	0.12	36.6
About the same or higher	†	*24.1*
Percent of withdrawn/failed STEM courses out of all STEM courses attempted through 2009		
More than 20 percent	0.28	53.5**
10–20 percent	0.20	46.3
Less than 10 percent	†	*26.0*
STEM GPA compared to non-STEM GPA through 2009		
Lower by at least 1.0 grade point	0.73	99.2***
Lower by 0.5 to 0.9 grade points	0.05	31.5
About the same or higher	†	*26.2*

**p< .05, ** p< .01, *** p< .001.*

† Not applicable for the comparison group.

NOTE: F-test for this MNP is 743.8 (p<0.001). The table includes high-performing STEM entrants who either persisted in STEM fields or switched majors to non-STEM fields. The base category for this MNP is "persisting in STEM fields."

Table 6. Average marginal effects of various characteristics on the probability of high-performing STEM entrants switching majors to a non-STEM field, and the average predicted probability of switching majors among various groups of students

4 CONCLUSION

Through analyzing survey and transcript data from BPS:04/09, this study contributes to some understanding of STEM attrition among high-performing students in U.S. postsecondary institutions. Several conclusions can be drawn from this study. First, although STEM attrition appeared high in U.S. postsecondary education,, many non-STEM fields experienced similar or even higher attrition rates. Switching majors, for example, was more common in such fields as education, health sciences, and humanities than in STEM fields. Thus, high attrition rates were not unique to STEM fields.

Second, high STEM attrition primarily occurred among low-performing students. The majority of high-performing students who entered STEM fields persisted in these fields. Given that STEM was one of the top major choices among high-performing students, over concern about losing top students in STEM fields may not be warranted.

Third, consistent with early research and proposed theories (Bettinger, 2010; Ost, 2010; Rask, 2010; Seymour & Hewitt, 1997), the results of this study point to several potential reasons for high-performing students switching STEM majors, including:

- *Poor performance in STEM courses*. The probability of switching majors for high-performing students was associated with poor STEM performance (as reflected by lower STEM grades relative to non-STEM grades and high volumes of withdrawn/failed STEM courses), suggesting that STEM coursework may have proved too challenging for some students, motivating them to switch to less difficult fields in which they could earn higher grades and have a better chance of success.
- *Weak focus on STEM coursework in the first year*. The probability of switching majors was higher among students who took significantly fewer STEM courses in the first year. Some students may be less committed to STEM majors or may have other commitments that compete with their STEM coursework; but regardless of their situations, the results of this study suggest that missing the opportunity to build early momentum in STEM coursework may lead students to abandon pursuing a STEM degree later on.
- *The lure of such fields as health sciences*. A significant proportion of high-performing students switched to health science majors, indicating that lucrative careers in health may draw top students into these fields as shown in early research (Bettinger, 2010; Shaw & Barbuti, 2010).

5 STUDY LIMITATIONS AND FUTURE RESEARCH

Three specific limitations of this research are worth noting. First, this study draws upon students' reported major fields to identify STEM entrants. Because BPS:04/09 collected students' majors only at three points in time and students could have had an unreported STEM major and STEM attrition could have occurred between the three data collection points, the number of STEM entrants and the extent of STEM attrition may be underestimated.

Second, because BPS:04/09 is a general purpose survey on postsecondary education, its questions and survey elements are not tailored to include all variables relevant to STEM attrition. Some data identified in the literature as potentially important to STEM attrition (e.g., institutional context, climate, and support for STEM learning; characteristics of STEM faculty; STEM-related preparation and experiences in high school; and noncognitive factors such as motivation, interest, confidence in learning STEM subjects) are not available or limited in BPS:04/09. Consequently, the multivariate analysis in this study cannot control for all factors that have been shown in prior research to be related to STEM attrition.

Third, past research suggests that there are some important distinctions among STEM fields. For example, the field of biology/life sciences often attracts more female students than do "hard" sciences such as physics, engineering, and computer sciences (National Science Board, 2012). In addition, attrition rates and the factors that affect students' departure decisions may vary across STEM fields (Kokkelenberg & Sinha, 2010; Ost, 2010; Rask, 2010; Shaw & Barbuti, 2010). While it is ideal to differentiate specific STEM fields, such an analysis is not feasible in this study due to the small number of high-performing students provided in BPS:04/09.

Given these limitations, future STEM research should continue to identify additional factors underlying students' choice of STEM majors and their long-term persistence in these fields. If sample sizes allow, a close examination of each STEM field (such as life sciences, physical sciences, engineering, computer sciences, and mathematics) will yield information that would help confirm whether factors influencing STEM attrition are common among or vary across different STEM fields. Future research can also explore issues related to when students change majors, how many times they make such changes, and which major fields students frequently move into or out of. Such an investigation would provide a better understanding of the dynamic decision-making process of individuals who enter, persist in, or leave STEM fields. Finally, future research can expand the findings of the current study by exploring students' transcript data more extensively, pinpointing which STEM courses, particularly which gatekeeper courses in the first 2 years, may hinder students' persistence in STEM fields.

NOTE

Some of the literature review for this study was adapted from an earlier STEM attrition report prepared for the National Center for Education Statistics (NCES) of the U.S. Department of Education (Chen 2013). While the earlier NCES report examined STEM attrition in the general undergraduate population, the current study addresses STEM attrition among high-performing students. The author was granted permission from NCES to use information from the previous report for the current study.

REFERENCES

Anderson, E., & Kim, D. (2006). *Increasing the Success of Minority Students in Science and Technology*. Washington, DC: American Council on Education.

Barr, D.A., González, M.E., & Wanat, S.F. (2008). The Leaky Pipeline: Factors Associated With Early Decline in Interest in Premedical Studies Among Underrepresented Minority Undergraduate Students. *Academic Medicine*, 83(5), 503-511. http://dx.doi.org/10.1097/ACM.0b013e31816bda16

Bettinger, E. (2010). To Be or Not to Be: Major Choices in Budding Scientists. In C.T. Clotfelter (Ed.), *American Universities in a Global Market* (pp. 68-98). Chicago: University of Chicago Press.
http://dx.doi.org/10.7208/chicago/9780226110455.003.0003

Borooah, V.K. (2001). *Logit and Probit: Ordered and Multinomial Models*. Sage University Papers Series on Quantitative Applications in the Social Sciences (07-138). Thousand Oaks, CA: Sage.

Burtner, J. (2005). The Use of Discriminant Analysis to Investigate the Influence of Non-Cognitive Factors on Engineering School Persistence. *Journal of Engineering Education*, 94(3), 335-338. http://dx.doi.org/10.1002/j.2168-9830.2005.tb00858.x

Carnevale, A.P., Smith, N., & Melton, M. (2011). *STEM: Science, Technology, Engineering, and Mathematics*. Washington, DC: Center on Education and the Workforce, Georgetown University.

Carrell, S.E., Page, M.E., & West, J.E. (2010). Sex and Science: How Professor Gender Perpetuates the Gender Gap. *The Quarterly Journal of Economics*, 125(3), 1101-1144. http://dx.doi.org/10.1162/qjec.2010.125.3.1101

Chang, M.J., Cerna, O., Han, J., & Sáenz, V. (2008). The Contradictory Roles of Institutional Status in Retaining Underrepresented Minorities in Biomedical and Behavioral Science Majors. *The Review of Higher Education*, 31(4), 433-464. http://dx.doi.org/10.1353/rhe.0.0011

Chang, M.J., Eagan, M.K., Lin, M.H., & Hurtado, S. (2011). Considering the Impact of Racial Stigmas and Science Identity: Persistence Among Biomedical and Behavioral Science Aspirants. *Journal of Higher Education*, 82(5), 564-596. http://dx.doi.org/10.1353/jhe.2011.0030

Chen, X. (2009). Students Who Study Science, Technology, Engineering, and Mathematics (STEM) in Postsecondary Education (NCES 2009-161). *National Center for Education Statistics, Institute of Education Sciences, U.S.* Department of Education. Washington, DC.

Daempfle, P. (2003). An Analysis of the High Attrition Rates Among First Year College Science, Math, and Engineering Majors. *Journal of College Student Retention: Research, Theory and Practice*, 5(1), 37-52. http://dx.doi.org/10.2190/DWQT-TYA4-T20W-RCWH

Eagan, K., Herrera, F.A., Garibay, J.C., Hurtado, S., & Chang, M. (2011). *Becoming STEM Protégés: Factors Predicting the Access and Development of Meaningful Faculty-Student Relationships*. Los Angeles: Higher Education Research Institute.

Ehrenberg, R.G. (2010). Analyzing the Factors That Influence Persistence Rates in STEM Field Majors: Introduction to the Symposium. *Economics of Education Review*, 29(6), 888-891.
http://dx.doi.org/10.1016/j.econedurev.2010.06.012

Espinosa, L.L. (2011). Pipelines and Pathways: Women of Color in Undergraduate STEM Majors and the College Experiences That Contribute to Persistence. *Harvard Education Review*, 81(2), 209-240.

Fouad, N.A., Hackett, G., Smith, P.L., Kantamneni, N., Fitzpatrick, M., Haag, S. et al. (2010). Barriers and Supports for Continuing in Mathematics and Science: Gender and Educational Level Differences. *Journal of Vocational Behavior*, 77(3), 361-373. http://dx.doi.org/10.1016/j.jvb.2010.06.004

Gayles, J.G., & Ampaw, F. (2014). The Impact of College Experiences on Degree Completion in STEM Fields at Four-Year Institutions: Does Gender Matter?. *The Journal of Higher Education*, 85(4), 439-468.
http://dx.doi.org/10.1353/jhe.2014.0022

Griffith, A. (2010). Persistence of Women and Minorities in STEM Field Majors: Is It the School That Matters?. *Economics of Education Review*, 29(6), 911-922. http://dx.doi.org/10.1016/j.econedurev.2010.06.010

Haag, S., & Collofello, J. (2008, October 22–25). *Engineering Undergraduate Persistence and Contributing Factors*. Paper presented at the 38th ASEE/IEEE Annual Frontiers in Education Conference, Saratoga Springs, NY.

Hill, C., Corbett, C., & Rose, A.S. (2010). *Why So Few? Women in Science, Technology, Engineering, and Mathematics*. Washington, DC: American Association of University Women.

Kelly, D., Xie, H., Nord, C.W., Jenkins, F., Chan, J.Y., & Kastberg, D. (2013). Performance of U.S. 15-Year-Old Studentsin Mathematics, Science, and Reading Literacy in an International Context: First Look at PISA 2012 (NCES 2014-024). *National Center for Education Statistics, Institute of Education Sciences, U.S.* Department of Education. Washington, DC.

Kokkelenberg, E.C., & Sinha, E. (2010). Who Succeeds in STEM Studies? An Analysis of Binghamton University. *Economics of Education Review*, 29(6), 935-946. http://dx.doi.org/10.1016/j.econedurev.2010.06.016

LeBeau, B., Harwell, M., Monson, D., Dupuis, D., Medhanie, A., & Post, T.R. (2012). Student and High-School Characteristics Related to Completing a Science, Technology, Engineering or Mathematics (STEM) Major in College. *Research in Science & Technological Education*, 20(1), 17-28. http://dx.doi.org/10.1080/02635143.2012.659178

Lowell, B.L., Salzman, H., Bernstein, H., & Henderson, E. (2009, November 7). *Steady as She Goes? Three Generations of Students Through the Science and Engineering Pipeline*. Paper presented at the Annual Meetings of the Association for Public Policy Analysis and Management, Washington, DC.

Méndez, G., Buskirk, T.D., Lohr, S., & Haag, S. (2008). Factors Associated With Persistence in Science and Engineering Majors: An Exploratory Study Using Classification Trees and Random Forests. *Journal of Engineering Education*, 97(1), 57-70. http://dx.doi.org/10.1002/j.2168-9830.2008.tb00954.x

Mervis, J. (2010). Better Intro Courses Seen as Key to Reducing Attrition of STEM Majors. *Science*, 330(6002), 306. http://dx.doi.org/10.1126/science.330.6002.306

National Academy of Science, Committee on Science, Engineering, and Public Policy (COSEPUP). (2005). *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: National Academies Press.

National Governors Association. (2007). *Building a Science, Technology, Engineering and Math Agenda*. Washington, DC: Author.

National Research Council. (2012). *Monitoring Progress Toward Successful K−12 STEM Education: A Nation Advancing?.* Washington, DC: National Academies Press.

National Science Board. (2010). *Science and Engineering Indicators 2010*. Arlington, VA: National Science Foundation.

National Science Board. (2012). *Science and Engineering Indicators 2012*. Arlington, VA: National Science Foundation.

National Science Board. (2014). *Science and Engineering Indicators 2014*. Arlington, VA: National Science Foundation.

Ost, B. (2010). The Role of Peers and Grades in Determining Major Persistence in Sciences. *Economics of Education Review*, 29(6), 923-934. http://dx.doi.org/10.1016/j.econedurev.2010.06.011

President's Council of Advisors on Science and Technology (PCAST). (2012). *Engage to Excel: Producing One Million Additional College Graduates With Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: Author.

Price, J. (2010). The Effect of Instructor Race and Gender on Student Persistence in STEM Fields. *Economics of Education Review*, 29(6), 901-910. http://dx.doi.org/10.1016/j.econedurev.2010.07.009

Rask, K. (2010). Attrition in STEM Fields at a Liberal Arts College: The Importance of Grades and Pre-Collegiate Preferences. *Economics of Education Review*, 29(6), 892-900. http://dx.doi.org/10.1016/j.econedurev.2010.06.013

Seymour, E. (2001). Tracking the Processes of Change in U.S. Undergraduate Education in Science, Mathematics, Engineering, and Technology. *Science Education*, 86(1), 79-105. http://dx.doi.org/10.1002/sce.1044

Seymour, E., & Hewitt, N.M. (1997). *Talking About Leaving: Why Undergraduates Leave the Sciences*. Boulder, CO: Westview Press.

Shaw, E.J., & Barbuti, S. (2010). Patterns of Persistence in Intended College Major With a Focus on STEM Majors. *The National Academic Advising Association Journal*, 30(2), 19-34.

Snyder, T.D., & Dillow, S.A. (2013). Digest of Education Statistics, 2012 (NCES 2014-015). *National Center for Education Statistics, Institute of Education Sciences, U.S.* Department of Education. Washington, DC.

Stinebrickner, T.R., & Stinebrickner, R. (2011). *Math or Science? Using Longitudinal Expectations Data to Examine the Process of Choosing a College Major*. NBER Working Paper No. 16869. Cambridge, MA: National Bureau of Economic Research. http://dx.doi.org/10.3386/w16869

Wang, M.T., Eccles, J.S., & Kenny, S. (2013). Not Lack of Ability but More Choice: Individual and Gender Differences in Choice of Careers in Science, Technology, Engineering, and Mathematics. *Psychological Science*, 24(5), 770-775. http://dx.doi.org/10.1177/0956797612458937

Whalen, D.F., & Shelley, M.C. (2010). Academic Success for STEM and Non-STEM Majors. *Journal of STEM Education*, 11(1,2), 45-60.

Zumeta, W., & Raveling, J. (2002). *The Best and Brightest: Is There a Problem Here?*. Washington, DC: Commission on Professionals in Science and Technology.

Citation: Chen, X. (2015). STEM attrition among high-performing college students in the United States: Scope and potential causes. *Journal of Technology and Science Education (JOTSE), 5(1), 41-59.* http://dx.doi.org/10.3926/jotse.136

On-line ISSN: 2013-6374 – Print ISSN: 2014-5349 – DL: B-2000-2012

AUTHOR BIOGRAPHY

Xianglei Chen

Xianglei Chen holds a B.S. in Electronic Engineering and Physics, an M.A. in Comparative Education, and a Ph.D. in Educational Foundation and Policy. Dr. Chen is a Senior Research Associate at RTI International and has more than 15 years of experience in conducting education policy research related to student access, progress, and success in high school and postsecondary education. In recent years, she has focused her research efforts on STEM education using high school and postsecondary transcript data.

Published by OmniaScience (www.omniascience.com)

Journal of Technology and Science Education, 2015 (www.jotse.org)